REMARKS

Claim 22 was rejected under 35 USC 112, second paragraph. Claims 22-28, 43, 44 and 46 were rejected under 35 USC 112, first paragraph. These rejections are respectfully traversed.

Applicants believe that they have overcome the rejections under 35 USC 112, first and second paragraphs, by changing "woven fabric comprising a resin comprising a solvent" to "woven fabric impregnated with a resin comprising a solvent" and by changing "wherein said solvent is substantially incompatible with said binder" to "wherein at least 80% of said solvent is incompatible with said binder" in claim 22, as amended so as to make this claim substantially similar to claim 22 in the Amendment of October 11, 2005.

Claims 22-28, 43 and 44 were rejected as being obvious over Kishi in view of Homma. This rejection has been overcome by adding the limitations of claim 45, now canceled, in claim 22.

Claims 45 and 46 were rejected as being obvious over Kishi in view of Homma. This rejection is respectfully traversed.

The Examiner states that the limitation of claim 45 was "previously addressed in the Final Rejection (11/02/05) and since said limitation is encompassed in the rejection of claim 22, claim 45 is also rejected for the reasons of record." See line bridging pages 5 and 6 of the Action. In rejecting claim 22 in the Action of November 2, 2005, the Examiner states the following in paragraph 3 of this Action:

> Applicant has amended independent claims 22 to limit the resin to being diluted with a solvent, wherein at least 80% of said solvent is incompatible with said binder. Applicant argues Kishi and Homma do not each said limitation (Amendment [of October 11, 2005], page 4, 5th paragraph). However, said amendment is insufficient to overcome the present rejection in that the claims are drawn to a cloth prepreg (i.e., final product) and the solvent is not present in said final product.

Applicants respectively submit that the Examiner's statement that "the solvent is not present in said final product" is incorrect. Persons of ordinary skill in this art would recognize

that a prepreg made by the wet process contains some solvent in the resin impregnating the fibers. See for example, a copy of page 149 of "Engineered Materials Handbook – Volume 1 – Composites," enclosed herewith. In this document, it is stated that a fabric prepreg by a wet process (which is termed as "solvent coating" in this document) has a residual solvent content of 1 to 2% in the resin. It is this residual solvent content in the cloth prepreg (i.e., *the final product*) that provides higher tack and better drape as compared to the tack and drape of a prepreg made by hot melt. See copy of page 149 of "Engineered Materials Handbook – Volume 1 – Composites," enclosed herewith.

Claim 22 has been amended to recite "woven fabric impregnated with a resin *comprising a solvent*." [Emphasis added.] In short, the solvent is a component of the cloth prepreg (i.e., the final product). Therefore, the Examiner is respectfully requested to no longer ignore the limitations "woven fabric impregnated with a resin comprising a solvent" and "wherein at least 80% of said solvent is incompatible with said binder." As explained in the Amendment of Amendment of October 11, 2005, Applicants again respectfully submit that Kishi and Homma *as a whole* do not teach or suggest "woven fabric impregnated with a resin comprising a solvent" or "wherein at least 80% of said solvent is incompatible with said binder."

Applicants submit that the pending claims, as amended, are now in condition for allowance. An early notice of which is respectfully solicited.

In the event that the transmittal letter is separated from this document and the Patent & Trademark Office determines that an extension and/or other relief is required, applicant petitions for any required relief including extensions of time and authorizes the Commissioner to charge the cost of such petitions and/or other fees due in connection with the filing of this document to **Deposit Account No. 03-1952,** referencing 360842003400.

Respectfully submitted,

Dated: October 6, 2006

Raj S. Davé, Ph.D., J.D.
Registration No. 42,465

Morrison & Foerster LLP
1650 Tysons Blvd., Suite 300
McLean, VA 22102
Telephone: 703.760.7755
Facsimile: 703.760.7777

Volume 1

ENGINEERED MATERIALS HANDBOOK™

COMPOSITES

ASM International

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Volume 1

COMPOSITES

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Foreword

Publication of Volume 1, *Composites*, of ASM INTERNATIONAL's new *Engineered Materials Handbook* is a signal event from many aspects.

It is a major step in fulfilling ASM INTERNATIONAL's commitment to expand its scope to include all materials of interest in the industries it serves, and new manufacturing areas as well. Future volumes in the *Engineered Materials Handbook* series will cover engineering plastics, ceramics, and other high technology materials.

It represents another major expansion of the ASM INTERNATIONAL handbooks publishing program, which began 60 years ago with a small looseleaf binder of metals properties data and other information. From this beginning the *Metals Handbook* has grown to the present 17-volume Ninth Edition, acknowledged worldwide as the definitive reference source for the metals and metalworking industry. With this inaugural volume, the *Engineered Materials Handbook* takes its place alongside the *Metals Handbook*, as a new series for the new materials.

It is the largest, most complete, most up-to-date single volume of in-depth engineering information on composite materials ever made available to the public. Its contents include articles on every essential topic pertaining to the use of composites: properties and forms of the basic fibers and matrix materials of which composites are made, as well as of the composite materials themselves; analysis and design of composite materials and of the structures made from them; testing of composites; manufacturing and fabrication processes; quality control; failure analysis; and applications and experience.

We are pleased to extend thanks and congratulations on behalf of ASM INTERNATIONAL to Technical Chairman Ted Reinhart and the volume's 18 Section Chairmen and Co-Chairmen, for the outstanding job they have done in recruiting an author list that includes many of the best-known authorities in the composites field. Our gratitude is also due these authors and the many reviewers who so generously donated their time and efforts to make this book a useful and authoritative reference. In addition, we express our appreciation to the ASM INTERNATIONAL editorial staff, for their hard work, diligence, and enthusiasm in beginning this new series at the same level of excellence so well established by the *Metals Handbook*.

William G. Wood
President,
ASM INTERNATIONAL

Edward L. Langer
Managing Director,
ASM INTERNATIONAL

Woven Fabric Prepregs

Fred S. Dominguez, Hercules Aerospace Company

WOVEN FABRIC PREPREGS are one of the most widely used fiber reinforced resin forms. Fabrics typically offer flexibility in fabrication technique, but at a higher cost than other prepreg forms. The designer must consider these and other factors before selecting a prepreg form for structural application.

Fabric Construction

Fibers can be woven into many different types of weave patterns, widths, and thicknesses. The warp yarns, or ends, lie in the lengthwise (machine) direction of the fabric, whereas the filling yarns, or picks, lie crosswise, at right angles to the warp yarn. Fabric construction is specified by the number of warp yarns per centimeter of fabric width and the number of filling yarns per centimeter in the lengthwise direction. Therefore, fabric weight, thickness, and breaking strength are proportional to the number and types of warp and filling yarns used in weaving.

A variety of weave patterns can be used to interlace the warp and filling yarns to form a stable fabric (see Fig. 1). The weave pattern controls the handling characteristics of a fabric and, to some degree, the properties of a product that uses it as reinforcement. Some applications require that all fabric construction variables be specifically designed so that the desired performance criteria can be met.

The plain weave, which interlaces one warp yarn over and under one filling yarn, demonstrates the greatest degree of stability with respect to yarn slippage and fabric distortion; yarn count and content, however, also contribute to fabric stability.

The basket weave has two or more warp yarns that interlace over and under two or more filling yarns. Although the basket weave is less stable than the plain weave, it is more pliable and will conform more readily to simple contours.

The twill weave interlaces one or more warp yarns over one and under two or more filling yarns in a regular pattern. This produces either a straight or a broken diagonal line in the fabric, which consequently has greater pliability and better drapability than either plain-woven or basket-woven fabric.

A crowfoot satin weave has one warp yarn interlacing over three and under one filling yarn in an irregular pattern, resulting in a pliable fabric capable of conforming to complex or compound contours.

The 8-end satin weave has one warp yarn interlacing over seven and under one filling yarn in an irregular pattern, which yields a pliable fabric that will readily conform to compound contours. Since this weave pattern allows a comparatively high yarn count per centimeter and fewer fiber distortions, it translates into better strength properties in all directions than a tighter weave, such as the plain weave. A variation of the 8-end satin weave is the 5-end satin weave.

Fabrics woven with heavy warp yarns and fine filling yarns in either the crowfoot or long-shaft (such as the 8-end) satin weave patterns are called unidirectional fabrics. These fabrics are characterized by a high strength contribution to composites in the heavy-yarn

Table 1 Graphite fabric forms

Weave	Construction, tows/cm	Construction, tows/in.	Weight, g/m²	Weight, oz/yd²	Thickness(a), mm	Thickness(a), mil
Plain	4.5 × 4.5	11 × 11	193	5.7	0.18	[illegible]
8-end satin	8.5 × 8.5	22 × 22	370	10.9	0.34	13.2
5-end satin	4.3 × 4.3	11 × 11	370	10.9	0.34	[illegible]
Crowfoot satin	4.1 × 4.1	10 × 10	185	5.5	0.17	6.7

(a) Cured ply thickness at 62 vol% fiber for high-strength, low-modulus fiber-epoxy prepreg

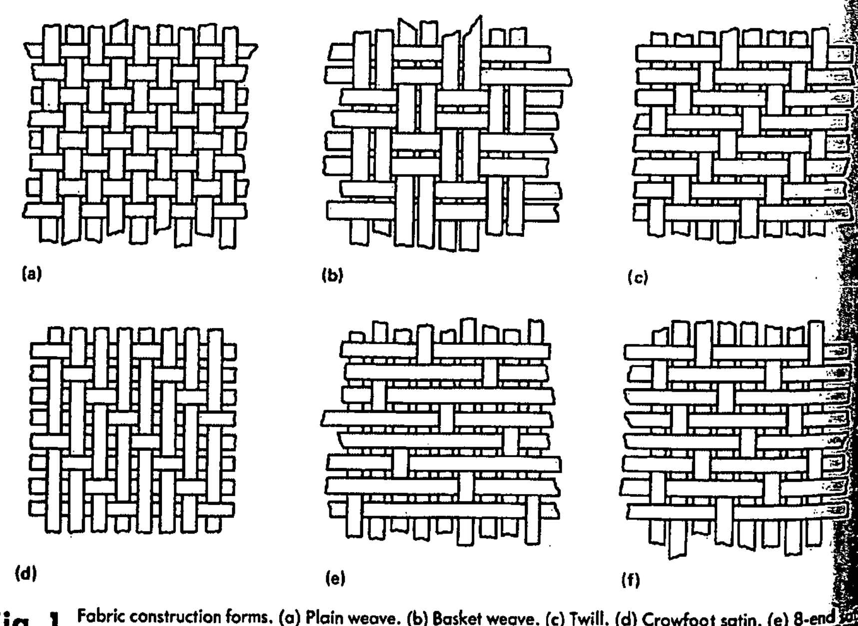

Fig. 1 Fabric construction forms. (a) Plain weave. (b) Basket weave. (c) Twill. (d) Crowfoot satin. (e) 8-end [illegible] (f) 5-end satin

Table 2 Properties of graphite, aramid and hybrid fabric composites compared to 0°/90° laminates made from unidirectional layers (data normalized to 65 vol% fiber)

Ratio of aramid to graphite fiber	Tensile modulus, 0°/90°, GPa	Tensile modulus, 0°/90°, 10^6 psi	Tensile modulus, fabric, GPa	Tensile modulus, fabric, 10^6 psi	Fabric efficiency, %	Tensile strength, 0°/90°, MPa	Tensile strength, 0°/90°, ksi	Tensile strength, fabric, MPa	Tensile strength, fabric, ksi	Fabric efficiency, %	Compressive strength, 0°/90°, MPa	Compressive strength, 0°/90°, ksi	Compressive strength, fabric, MPa	Compressive strength, fabric, ksi	Fabric efficiency, %
100/0	36.5	5.29	35.8	5.19	98	579	84.0	544	78.9	94	165	23.9	152	22.0	92
50/50	55.1	7.99	48.2	6.99	87	572	83.0	400	58.0	70	407	59.0	227	32.9	56
25/75	69.6	10.1	57.2	8.30	82	661	95.9	434	62.9	66	641	93.0	317	45.0	49
0/100	72.3	10.5	59.9	8.69	83	730	105	434	62.9	59	965	140	558	80.9	58

Source: Ref 2

(warp) direction. Table 1 shows typical graphite weave patterns.

Nonwoven unidirectional fabrics can be produced by chemically bonding the warp and filling yarns rather than interlacing them. Although the chemical bonding contributes to the stability of these nonwoven products, they tend to be somewhat firm and therefore do not readily conform to complex or compound contours (Ref 1).

The handling characteristics of a fabric are determined by the yarn count and the weave pattern holding the yarns together. If the weave pattern is too tight, the fabric will not conform to various contours and will not accept resin, resulting in a weak composite. On the other hand, if the weave pattern is too open or loose, the fabric will not contain sufficient fiber to attain its maximum possible strength and will be easily distorted, precluding the alignment of the fibers with preferred strength axes.

Because precise fiber orientation is necessary for optimum translation of fiber properties, it is critical that fabrics be aligned properly on the tool surface. To achieve this, tracer yarns can be woven into the fabric, particularly a graphite fabric. The tracer provides a very fine (small denier) fiber of contrasting color that can be used by the fabricator to verify fiber direction in the warp and fill directions. This tracer is also used by the prepregger to verify correct orientation of warp and fill tows during prepreg operations. In addition, if the tracer contains x-ray detectable pigment, it can be used to verify ply orientation and count in cured laminates.

Table 3 Impact resistance of hybrid composites

Hybrid composite(a), wt%	Izod impact strength, unnotched, J/m	Izod impact strength, unnotched, ft·lbf/in.
Graphite, 100%	1495	28
Graphite, 75%; aramid, 25%	1815	34
Graphite, 50%; aramid, 50%	2349	44
Aramid, 100%	2562	48
Graphite, 100%	1495	28
Graphite, 75%; glass, 25%	2349	44
Graphite, 50%; glass, 50%	2989	56
Glass, 100%	3843	72

(a) With epoxy matrix. Source: Ref 1

Fabric Prepreg Forms

Fabrics can be prepregged using either a hot-melt or a solvent-coating process. The hot-melt process uses a machine similar to that used for fabricating unidirectional tape. Resin can be applied to the fabric either by using prefilmed substrate paper, a "knife over roll," or a similar coating mechanism. Solvent coating is typically accomplished by immersing the fabric into a bath containing 20 to 50% of a solvent and resin mixture and then drying the fabric in a one-pass or multipass former coater. The two techniques generate different characteristics in the prepreg:

Hot melt

- Less drape and lower tack, due to higher resin viscosity, which in turn is due to lack of residual solvent in the prepreg
- Better hot/wet mechanical properties, less flow, and longer gel time, due to the absence of volatiles
- Higher cost, due to slower process speed and higher resin scrappage

Solvent coating

- Better drape, due to lower resin viscosity and, usually, higher tack
- Residual solvent of 1 to 2%, which incurs longer gel time, higher flow, and lower hot/wet mechanical properties
- Lower cost, due to increased process speed and reduced resin waste

Hybrids

Hybrid fabrics are those woven from several different types of fibers, in contrast to fabrics woven from a single type of fiber. Table 2 shows typical properties of one hybrid graphite/aramid fabric. Combining fiber reinforcements allows the designer considerable flexibility. Among the reasons for the hybridization of graphite composites are (1) adding another fiber to a predominantly graphite composite in order to overcome the inherent disadvantages of graphite, (2) adding graphite fibers to a predominantly nongraphite composite or structure in order to take advantage of the benefits of graphite, and (3) producing a lower-cost structure. Normally, the impact resistance of graphite fiber composites can be improved by adding high-strength fibers with a greater strain-to-failure ratio than graphite. Several energy-absorbing mechanisms that have been proposed include interlacing resin layers to absorb energy and using fillers to stop cracks. Table 3 shows typical hybrid graphite/aramid and graphite/glass impact properties.

Graphite hybrid composites can be fabricated using conventional techniques and can be com-

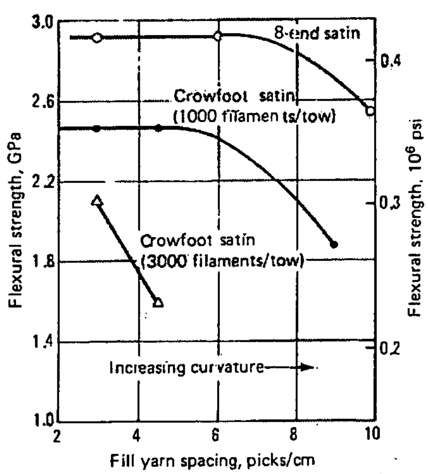

Fig. 2 Influence of fabric construction on graphite composite flexural strength (data normalized to 100 vol% warp fiber)

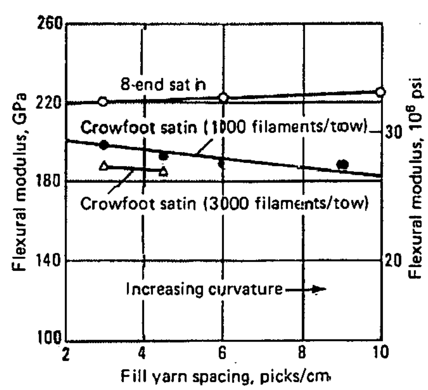

Fig. 3 Influence of fabric construction on graphite composite flexural modulus (data normalized to 100 vol% warp fiber)